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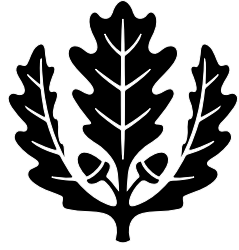
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# University of Connecticut

*Department of Economics Working Paper Series*

**On Modeling and Controlling the Effects of Variable Labor Effort: A Theoretical Explanation of the Truck System**

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## **Abstract**

In most Industrial and Industrializing Countries, labor markets are characterized by employers offering packages of wage, non-wage, and working conditions to prospective workers. In return, workers offer to apply effort to tasks determined by employers. This paper attempts to examine these employer-employee contracts using a stockout avoidance model with employees providing variable labor effort.

# 1 Introduction

In industrial and industrializing countries, labor markets are characterized by employers offering packages of wage and non-wage payments (in the form of fringe benefits and working conditions) to prospective workers. In return workers offer to apply effort (which is often measured by "hours paid for" per week) to tasks determined by the employer. However detailed, employer-employee contracts can never be complete, in the sense that they can do no more than specify a minimal expected product (usually expressed in terms of an approximate number of hours of input) and some subset types and quantities of remuneration. Among other things this lack of specificity in contracting results from the agents' inability to specify all of the contingencies possible in an uncertain and risky world. The lack of precision in contracting also allows for variable performance on the part of the firm and the worker. This paper will focus on the variability of workers' effort and the attempts by firms to lower and accurately predict that variability since we argue that such variability can be costly in many industries<sup>1</sup>.

More specifically we will term the worker's contribution to output "effort" (in lieu of the common measure "hours paid for") and the firm's payment to workers as compensation. In this paper we argue that employers can vary the components of this compensation not only to increase effort, but most importantly for the purposes of this work we will argue that employers alter the composition of compensation not only to increase effort but to lower its variability because variable effort in modern continuous process production is costly. Thus we argue that firms use the composition of compensation to influence the variability of labor effort.

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<sup>1</sup>This paper has direct and clear applications to problems in economic development, economic history, economic organization and labor economics. Given appropriate data for example on piece rates and their variability among workers, the hypotheses presented here are empirically testable.

The ways in which institutional wage-performance structures have evolved so as to minimize effort variability and increase the predictability of daily labor productivity are at least fourfold. First, firms may hold inventories of goods at every stage of production to assure against unexpected interruptions in the effort flow; but, such inventories are costly to maintain. Second, firms may obtain information concerning the potential flow of effort from various sources such as alternative forms of monitoring (e.g., direct supervision), information from past work histories, various forms of certification, examinations, and so on. These sources of information are used to elicit and predict the effort forthcoming from the firm's labor force. In addition to goods inventorying and monitoring, incentive payments may be employed to assist in obtaining a predictable and maximal application of effort; for example, piece rates, contests and bonuses.<sup>2</sup>

Finally, as is shown below, firms using information gained through compensation in-kind may elicit from their work an effort flow that is less costly to forecast and has (or probably has) lower variability than the effort flow elicited in the absence of an all-cash compensation structure. To the extent that in-kind payments have lower costs than other forms of monitoring and incentives and achieve equal or better outcomes firms will use them as substitutes for other information gathering mechanisms.

In addition to assisting in effort observation and lowering the variability of the effort flow, it is likely that firms will use payments in-kind to make human capital investments in their workers with the goal of increasing both their productivity and effort. To the extent that the workers' marginal productivity is increased by these investments and to the extent that this increase is firm specific, its costs will be shared by workers and firms. We will ignore this aspect

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<sup>2</sup>We will use the terms effort variability and effort predictability as equivalent in meaning. That is, as employers either lower variability or obtain more information concerning the variability (holding the level of variability constant) of the effort flow, it will become predictable with a higher degree of precision.

of compensation composition. With the exception of noting that fringe benefits (compensation composition) is well known to be used to raise worker productivity. For example, in developing countries workers are often provided a meal on the job. This not only keeps them at the worksite but provides them with nutrition which they would otherwise not receive.<sup>3</sup>

The paper proceeds as follows: In the next section the problem of effort variability is presented in a historical context. Section 4 describes the model of uncertainty concerning labor effort and the costs of (for example) increasing inventories which lead to higher production and higher employment and labor costs. Further the section describes workers who will respond with smaller variability of effort to a wages plus a portfolio of goods that are positively correlated with effort. Section 3 provides a small bit of evidence of the plausibility of this hypothesis. The final section presents conclusions and recommendations for further exploration of this problem.

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<sup>3</sup>This point regarding human capital investments has been made several times in the past. See among others: Becker, Mincer, Owen and Olsen.

In a related area (as noted in the text) we will also disregard other aspects of in-kind compensation such as productive consumption, whereby firms increase the mean level of effort (and productivity) of their workforces.

We will also ignore other rationales for payments in-kind, such as price advantages for in-kind payments derived from preferential tax treatment, and economies of group purchase, as well as their payment in response to trade union pressures, their effect of reducing costly worker turnover, and their payment in particular industries or to particular demographic groups of workers (e.g., in-kind payments seem to be demanded by older workers). (See Alpert (1982 and 1983).

In a related context, Hilton notes four rationales for the "truck system" (the designation of the in-kind payments scheme in Britain during the Industrial Revolution). The first is an increase in the firm's ability to exercise monopoly power and reduce wages through this contractual system. Second, the use of this system may reflect the existence of a form of "wage illusion" through which the firm cuts real wages by raising the prices charged to the workers for in-kind payments (company store model). Third, payment in-kind allows the length of time between paydays to be increased, thereby lowering the frequency of pay days. This procedure limits the capital tied up in wage payments and allegedly makes non-wage payments, when coupled with compulsion to deal with a company facility (e.g., by payment in script), allow employers to force workers into debt. It was argued that this debt bound workers to the employer and also forced the heads of large households into greater debt and hence permitted them less job mobility than other individuals.

## 2 The Problem of Effort Variability and the Effort Production Function

The importance of effort variability is most apparent during the development of modern industrial economies. We can use particular examples of the import of effort variability from the industrializations of Europe and the United States in the 19th Century as well as in modern industrializing economies. Unlike means of earning a living in traditional societies, factory work requires a predictable, coordinated and usually even flow of effort from the labor force. This type of effort is contrasted with the more variable and less predictable worker effort which, given the technology and capital of the period, did not necessarily inhibit efficient production in pre-industrial societies.

It is assumed that each worker transforms physical inputs (food, sleep, intellectual study, practice and so on) into effort. That effort when combined with physical capital and other resources performs the production of output. For example the physical input food is transformed into effort, where the quality and amount of food affect the effort flow.

**(Insert Figure Here)**

Knowledge about the foods (nutrition content of the foods) consumed by workers will yield information to the firm regarding both the mean effort that employers may expect to receive from workers as well as information regarding the variability of that effort. This paper concerns itself with the latter phenomena. The firm could obtain knowledge about consumption patterns by directly monitoring the inputs of workers into their bodies. Or, as proposed here, the firm could make it relatively costly for workers to consume anything other than inputs which would elicit

a predictable flow of effort by paying compensation in-kind. More precisely, with information obtained from the control of consumption through in-kind payments, the firm could both reduce the variance of worker effort as well as calculate it more accurately. Thus, by manipulating relative prices (for example through payment in-kind) the firm may control the consumption bundle of its workforce to some extent. It could, for example, provide high quality housing in close proximity to the workplace, nutritious food and medical care which would lower the variability of the effort flow from labor (and probably increase its mean as well). The firm might even choose to provide goods such as liquor, poor quality food and so on so long as the goods were dispensed in such a way so as to make the effort flow more predictable.<sup>4</sup>

Therefore, a firm that pays in-kind will achieve higher profits *ceteris paribus* than a firm that does not make such effort-predicting payments. If there are costs incurred by this procedure, the firm will increase its payments in non-money compensation until the marginal benefits of increasing in-kind payments are equal to the marginal costs of doing so.

The idea that firms remunerate in-kind to affect and monitor the variability of worker on-the-job effort has intuitive appeal because workers spend substantially larger amounts of time in non-work environments than in work environments. A 40 hour per week worker (with a one hour lunch break and two 15 minute breaks during the day) spends only 19 percent of their weekly time at work leaving 81 percent of their time their own. Direct monitoring of the non-work environments is undoubtedly very costly. Payments in-kind are likely to be a relatively low cost

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<sup>4</sup>Suppose, for example, the firm sells liquor only in one and one-half ounce non transportable containers, and only between the hours of 5 p.m. Saturday and 2 a.m. Sunday. Suppose further, that this practice results in a high (prohibitively high) relative price at other times during the week. The firm knows that under this system up to five percent of its workers will be ill as a result of drinking on any given workday whereas, under a purely public market distribution system for liquor the number "out sick" due to excessive liquor consumption will vary between zero and fifty percent. With free market distribution the average rate of absenteeism will be higher and the higher absence rates will occur anytime the worker decides to have a party. In the firm price subsidized environment less variation will likely occur.



substitute for such direct monitoring of the production of potential effort by workers away from the work place.<sup>5</sup>

While employers have often called for a smooth flow of labor effort they have rarely enunciated the smoothing of work effort as one of their goals; however, evidence consistent with this hypothesis is plentiful. For example, a well-known commentator on managers' behavior in the industrial revolution in Britain notes that, "what was needed was regularity and steady intensity in place of irregular spurts of work.." <sup>6</sup>

Many early industrialists attempted to control as much of the non-work environment as possible. Usually these attempts are explained as an extension of the old order's "paternalism," or some more modern version of it. Yet this conclusion may not be warranted. T. S. Ashton notes that a unique new industrial system emerged in the early 19th Century in which new forms of labor contracts were introduced. Ashton argues that,

The second generation of employers was perhaps more alive than the first to the *losses that might arise from irregular or carelessness on the part of labour*. Men trained in the concern were appointed as managers and foreman; piece-rates and bonus schemes were introduced to stimulate effort; and fines were imposed for drunkenness, sloth and gaming. The new methods of administration, the new incentives, and the new discipline were as much a part of the revolution as the technical innovations themselves... [emphasis added]<sup>7</sup>

The most well-known attempt to lower the variance in effort and hence increase predictability,

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<sup>5</sup>A historical example of a case of total environmental monitoring is that of American Slavery

<sup>6</sup>Pollard, p. 181

<sup>7</sup>Ashton, p. 85.

examined intensively by George Hilton, is the Truck System. Hilton notes that

It was widely suggested in the nineteenth century that .... the truck system was a sumptuary device, an effort by employers to reduce drunkenness among their workmen.<sup>8</sup>

Company stores were not always used for the capturing of rents from workers. Often goods were priced below retail, and it is a tenable hypothesis (awaiting significant historical data mining) that even though average prices were probably higher in truck shops, firms followed a policy of pricing products thought, at the time, to be substitutes for work or "effort randomizers" (especially liquor and other "nonproductive" goods) at relatively high prices and price goods thought, at the time, to be complements to work or effort stabilizers-predictors at relatively low levels.

Additional evidence that firms attempt to stabilize workers' effort by in-kind remuneration is offered by Sumner Schlichter. He characterizes the effects of "modern" personnel relations (circa 1920) in the following way:

If the worker has a toothache, the company dentist will cure it; if he has a headache or a cold, he can get treatment from the company doctor; if he or a member of his household needs an operation, the company doctor will help him find a competent surgeon; in some cases the company optometrist will measure him for glasses, and the company chiropodist will treat his corns. If he has legal difficulties, he can obtain free advice from the company's lawyer; if his wife or children are sick, a nurse from the company will visit his home to render such assistance as she can; if he wishes to

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<sup>8</sup>Hilton, p. 7

save money, the company will act as agent for a bank, deduct the money from his paycheck, deposit it in the bank, and do the bookkeeping for him; if he needs to borrow money, the company will lend it to him at a low rate of interest; if he wishes to own his own home the company will build one for him and sell it to him on easy terms... <sup>9</sup>

The purpose of these payments clearly seems to be one of stabilizing and predicting worker performance. Equivilient policies today might include on site day care centers and satellite charter schools, etc.

In summary, this paper does not propose that the current or historical rationales for in-kind compensation are unimportant. The thesis presented here is simply that by using in-kind payments as part of compensation modern firms using continuous process production techniques seek to predict and lower the variability of the effort flow of its labor. The firms do this so that they may better ascertain the actual price of labor services when they are applied to a fixed capital stock. This creates the ability on their part to earn higher profits than firms that do not behave in such a manner. In short, we propose that by monitoring compensation, firms can learn the variance of effort forthcoming from their workforce with greater precision. Moreover, through payments consisting of the appropriate consumption bundle, firms can actually reduce the variance and hence know the effort forth coming at any moment in time with greater certainty since its variance is smaller.

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<sup>9</sup>Schlichter, p. 433

### 3 Some Casual Evidence

Simply stated our hypothesis is that the more technically integrated a production process the more costly variable labor effort becomes. Therefore the more technically integrated production processes are the more likely it is that firms will use in-kind compensation to lower the variance of the flow of effort to that production process and by doing so make that variance more predictictable.

This suggests to us that goods producing firms are more likely to pay in-kind than are service producing firms. According to the most recently available Bureau of Labor Statistics research contained in *Employee Benefits in Private Industry, 2000*<sup>10</sup> That publication concludes that "Goods-producing industries had a higher incidence of coverage than service producing industries." This is illustrated in the table below:

**Incidence of Various Types of Benefits**

(Percent of Workers With Coverage)

Benefit/Sector	Retirement	Health Care	Life Insurance	Accident Insurance
Goods Producing	61	69	69	55
Service Producing	44	48	51	39

Benefit/Sector	Survivor Insurance	Paid Sick Leave	ST Disability	LT Disability
Goods Producing	55	42	45	31
Service Producing	39	57	30	24

<sup>10</sup> Available at <http://www.bls.gov/ncs/ebs/home.htm>.

Benefit/Sector	Paid Vacations	Paid Holidays	Dental Care	Vision Care
Goods Producing	84	84	33	20
Service Producing	77	71	28	17

This table illustrates that workers in the goods producing sectors have higher incidence of benefits in every category of benefits surveyed than workers in the service producing sectors. We assert that predictability of effort is more important in the goods producing sector than in the service sector; thus the prevalence of non-wage compensation in the goods producing sector.

While it is clear that this simple table holds only one factor constant and many other possible causes of differing compositions of compensation need to be considered prior to reaching any convincing determination of the empirical validity of the hypothesis, these data are inconsistent with the hypothesis. Therefore, even today the hypothesis that firms use the composition of compensation to lower (or even to make more predictable) the variability of effort may have validity.

## 4 The Model

### 4.1 Firms

Consider a firm with the following production technology.

$$y_t = \theta l_t \tag{1}$$

Where  $l_t$  represents labor effort. Labor will distributed  $N(\bar{l}, \sigma_l^2)$  and is perfectly observable by the firm. However, the firm must choose labor hours before observing time  $t$  effort. Note that for a given choice of labor, output will be distributed  $N(\bar{l}, \sigma_l^2)$ .

The firm faces an exogenous demand, denoted  $d_t$ , represented by the following  $AR(1)$  process:

$$d_t = d + \rho d_{t-1} + v_t \quad (2)$$

$$v_t \sim N(0, \sigma_v^2) \quad (3)$$

where  $0 \leq \rho \leq 1$ . The maximum amount a firm can sell in period  $t$  is its inventory at the end of period  $t - 1$ , denoted  $I_{t-1}$ , plus any production during period  $t$ . Let the price of output be given by  $p$  and denote the wage by  $w$ . Given a firms acquired inventories and assuming that  $p$  is sufficiently high, sales at time  $t$  will be given by

$$S_t = \min [I_{t-1} + y_t, d_t] \quad (4)$$

where  $S_t$  denotes actual sales at time  $t$ . Profits at time  $t$  are simply  $pS_t - wl_t$ . The problem facing the firm is to choose labor each period to maximize the present discounted value of profits.

$$E_{t-1} \left[ \sum_{s=t}^{\infty} (1+r)^{s-t} (pS_s - wl_s) \right] \quad (5)$$

Subject to demand (2) , the sales constraint (4), and the transition function for inventories

$$I_t = \max [I_{t-1} + y_t - d_t, 0] \quad (6)$$

Note that the firm must make production decisions prior to the observation of the demand shock  $v_t$ . The upshot of this dynamic programming problem is the following efficiency condition.

$$w = \Pr \{D_t \prec I_{t-1} + y_t\} (1 + r)^{-1} w + \Pr \{D_t \succ I_{t-1} + y_t\} p \quad (7)$$

The intuition behind this is simple. The left hand side represents the marginal cost of an additional unit of output. Once produced, there are only two possible outcomes. If current demand is less than currently available product, the the unit of output goes into inventories which allows production (and, hence, costs) next period to be lowered by one unit. The other possibility is a stockout. In this case, every produced unit of output is sold at the market price  $p$ . For simplicity, let  $A_t = I_{t-1} + \theta l_t - E(d_t)$ . Equation (s) can be rewritten as follows:

$$w = \Phi \left( \frac{A_t}{\sigma^2} \right) (1 + r)^{-1} w + \left( 1 - \Phi \left( \frac{A_t}{\sigma^2} \right) \right) p \quad (8)$$

Where  $\Phi()$  is a standard normal cumulative distribution function and  $\sigma^2 = \sigma_v^2 + \sigma_l^2 - 2cov(v, z)$ . From the first order condition, if  $c, p, w$  and  $r$  are constant, then  $A_t$  is constant as

well. It is straightforward to show that

$$A_t = A = \Phi^{-1} \left( \frac{p - w}{w - (1 + r)^{-1} w} \right) \sigma^2 \quad (9)$$

Given (8), the optimal production and inventory decisions are as follows:

$$y_t = -I_{t-1} + E(d_t) + A$$

$$I_t = \max [I_{t-1} + y_t - d_t, 0] = \max [A - v_t, 0] \quad (10)$$

$$l_t = \left( \frac{1}{\theta} \right) (-I_{t-1} + E(d_t) + A) \quad (11)$$

Therefore, as uncertainty concerning labor effort grows ( $\sigma_l^2$  increases), average inventory holding must increase to avoid stockouts. Higher inventory holdings implies higher production and, hence, higher average employment. Specifically, assume that demand and effort disturbances are uncorrelated. Then, from (9) and (11), the change in the firm's average per period labor bill is

$$\frac{\partial lw}{\partial (\sigma_l^2)} = \left( \frac{w}{\theta} \right) \Phi^{-1} \left( \frac{p - w}{w - (1 + r)^{-1} w} \right) \quad (12)$$

Hence, if firms can offer a wage contract that can lowers that variability of labor hours, they can lower their overall labor bill land, hence raise profits.



## 4.2 Households

Consumers have preferences defined over random streams of consumption and leisure represented by the expected utility function

$$J(s; \xi) = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \quad (13)$$

$$\beta < 1 \quad (14)$$

$$U(c, l; \lambda) = \ln(c) - \phi \frac{l^{1+\nu}}{1+\nu}$$

$$\nu > 0$$

where  $c$  represents consumption,  $l$  represents labor,  $\beta$  is the discount rate and  $E_0$  represents the conditional expectation based on information available at time 0. The form of the utility function is justified by Greenwood, Rogerson, and Wright (1994) as being consistent with household production theory. For simplicity, utility is separable in consumption and labor. The results will not be affected qualitatively by this. The term  $\phi$  represents the state of technology in the household production sector and is distributed *i.i.d.*  $N(1, \sigma_\phi^2)$ . Consumers receive income through wage contracts negotiated with the firm. These contracts can contain both wage and non-wage income. For now, assume the contract simply states a constant hourly wage.

$$y_t = w_t l_t \quad (15)$$

Income can be allocated for consumption purposes or can be saved. Savings earns the real rate of interest. Therefore, consumers face the following budget constraint.

$$c_t + s_{t+1} = w_t l_t + (1 + r_t) s_t \quad (16)$$

the household's decision problem is to choose a contingency plan for  $\{c_t, l_t, s_{t+1}\}_{t=0}^{\infty}$  that maximizes expected lifetime utility subject to the budget constraint.

The household's problem can be cast in the following recursive formulation. Note that to save on notation, time subscripts have been left out. Primed variables indicate their  $t + 1$  values.  $\xi$  represents the state of the world which will be defined later.

$$J(s; \xi) = \underset{c, l, s'}{Max} \left\{ \begin{array}{l} W(c, l) + \beta E_t J(s'; \xi') \\ + \lambda (w l + (1 + r) s - c - s') \end{array} \right\} \quad (17)$$

The upshot of the dynamic programming problem are the following first order conditions

$$W_1(c, l) = \lambda \quad (18)$$

$$-W_2(c, l) = w \lambda \quad (19)$$

$$\beta E J' (s'; \xi') = \lambda \quad (20)$$

Along with the following envelope condition

$$J' (s; \xi) = \lambda (1 + r) \quad (21)$$

Equation (18) is the efficiency condition for consumption. The multiplier  $\lambda$  represents the marginal utility of wealth. Equation (19) is the first order condition for labor. Equation (20) is the efficiency condition for savings. These conditions can be reduced to the following restrictions on consumption and labor.

$$l_t = \left\{ \frac{w}{\phi c_t} \right\}^{\frac{1}{\nu}} \quad (22)$$

$$E_t \left\{ \frac{c_t}{c_{t+1}} \right\} = \frac{1}{\beta (1 + r)} \quad (23)$$

Note that a positive shock to productivity in the household sector lowers labor effort in the production. Further, given the variability of household productivity, the variability of labor effort will be a negative function of  $\nu$  which is a measure of the concavity of household production.

$$\begin{aligned}
\sigma_l^2 &= \Omega(\sigma_l^2, \nu) \\
\Omega_1(.) &\succ 0 \\
\Omega_1(.) &\prec 0
\end{aligned} \tag{24}$$

### 4.3 Non-Wage Benefits and Effort Variability

Suppose that the firm wrote labor contracts that included non wage benefits as well as a contracted wage rate. Specifically, suppose that the firm offered a contract that specified a fixed wage plus a portfolio of assets with random payouts that were positively correlated with a workers household productivity. Specifically,

$$w = \tilde{w} + \pi(\phi) \tag{25}$$

$$\pi' \succ 0, \pi(1) = 0 \tag{26}$$

Note that this has no effect on the firm's wage commitment per hour, but it will lower the firm's wage bill (and, hence, profitability) by lowering the the variability of labor effort. Recall that by lowering labor effort variability, the firm can lower its variability of output. Therefore, less inventories are required to avoid stockouts which lowers average production. In fact, choosing the correct structure of the contract could in principle lower the variability of labor effort to zero.

The question remains, however, if the household would be willing to accept the contract. The

answer here should also, in general, be yes. Note that utility is concave. Therefore, we know that

$$E[U(x)] \prec U[E(x)] \tag{27}$$

Therefore, a contract that insures the worker against productivity shocks would lower the variability of labor and consumption and, hence, raise expected lifetime utility.

## 5 Conclusions and Recommendations

Since the dawn of the industrial age commentators have continually alluded to the need for continuous process manufacturing industrial employers to stabilize or at least to predict the flow of labor effort. This paper argues from the historical and casual empirical evidence this a possible way of lowering the variability of effort is employers altering the mix of compensation between money and a variety of commodities that not only help to increase effort, but also help to lower its variability. We use a stock out model of inventories to show that this conclusion is theoretically reasonable. Prior to full acceptance of the hypothesis much empirical work needs to be undertaken. For example, we might examine firms in which the predictability of effort flow is important and those in which intermittent effort flow is inconsequential and determine the composition of compensation in each with the expectation that effort predictors would form a higher proportion of compensation in the firms demanding a smooth effort flow. We also might look at prices in company stores to determine whether or not firms owning company stores

priced the substitutes to work effort relatively higher than the complements to work effort. Therefore this paper is simply a first step in solving what we believe to be an intriguing issue in compensation composition.

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Potential Output = Actual Output/Period

